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THE GAS-ENGINE IN THE COMMERCIAL DEVELOPMENT OF KANSAS.

By P. F. WALKER, Lawrence.

THE state of Kansas is well situated with reference to the great producing sections of the country for the establishment of important manufacturing interests in cotton and woolen fabrics, boots, shoes, and leather novelties, and has itself mineral resources of various kinds not yet fully developed, and which are now being shipped as raw rather than as finished products. With these advantages of location, and native resources in material to be wrought upon, are valuable deposits of coal, oil and gas for fuel, building materials of the very best quality, a soil capable of supporting a far greater population than the liveliest imagination has pictured, and a climate well suited to attract the earnest home-seeker. The question, then, may be seriously considered if a fair proportion of these raw materials may not well be expected to be worked upon here in the not far distant future, instead of their being shipped far into the Northern and Eastern states and then back again, in great part for final consumption by those who are working to send food on its long journey to pay the debt.

There are three conditions which must be favorably met before business interests of the kinds indicated can be successfully established. When once it is demonstrated that they are favorable here in Kansas, the necessary capital will come unbidden, and there will set in a new era in industrial development. These three conditions are: First, efficient and economical transportation facilities, both to the mills and to the markets; second, a supply of competent labor; and, third, an abundant and economical source of power. Other special conditions may sometimes arise, as, for instance, the necessity for a supply of clear water, to be used in the manufacturing process; but the three general conditions must always be met.

In respect to transportation the state is peculiarly fortunate, and better conditions could hardly be desired. This is especially true because of the fact that the power to be depended upon is not scattered over the country at falls in the watercourses, but the mills may be located at will on trunk railroad lines.

The labor condition is a serious one. Practical mill men have expressed the opinion to the writer that this is the greatest obstacle

to be overcome in locating the textile mills and boot and shoe manufactoryes in a new country. Operatives must acquire a certain skill, requiring time and patience, and a tolerable acute intellect, and the surroundings in which they work are trying to the constitution, particularly for those who have been accustomed to an outdoor life. Those who have been reared in the atmosphere of the mills—often too literally so, in the absence of restrictions on child labor—make competent workers, but they shrink from going into a distant field, where the number of mills is small and changes of situation not easily effected, since they are inclined to make frequent changes. In the movement to establish cotton-mills in the Southern seaboard and Gulf states, which has been successful, dependence has been placed on the white people of the mountain sections to supply the demand for labor. It seems doubtful if there is a class in Kansas that will take kindly to the work, and it will take time to develop a mill population.

In the consideration of power we come to the real subject-matter of this paper. The demand for power in nearly all of the industries referred to is considerable, and serious variations in the cost of power affect the dividend-paying possibilities to a considerable extent. For illustration, we may take a cotton-mill of 50,000 spindles, which will produce 25,000,000 yards of dress goods of average weight per annum, and compare power costs when driven by water power and when driven by steam-engines. This mill will require an invested capital of about \$750,000. It will require 1800 horse-power to run the machinery. The average cost of water power, when available for direct application, is about \$12.50 per horse-power per year at the New England mills, giving a total annual cost of \$22,500. For the steam-driven mill we will assume a first-class type of compound condensing engine, good boilers, and a high-grade coal, costing \$5 per ton delivered on the boiler-room floor. The first cost of installation will be about \$52 per horse-power—not materially different from that of the water plant. Allowing five per cent. of cost of machinery to cover the items of depreciation and repairs, a fuel consumption of two and one-fourth pounds of coal per horse-power per hour, and \$3000 per year for labor in the engine- and boiler-rooms, we have, for a year of 300 days of ten hours each, a total cost of nearly \$38,000, which is \$15,500 more than the cost of water power. This difference is 2.1 per cent. of the total investment, and is a direct inroad on dividends, being enough to effectually prohibit operations in many cases.

Now, then, what are the possibilities here in Kansas?

Before leaving the question of water power it will be well to consider briefly one phase of the matter that may become of importance. Water-power privileges are not numerous in Kansas, but there are a few points where power in large amounts could be produced, and from it electric power be generated directly and transmitted at high voltage to convenient points for the establishment of mills, where it can be used through the medium of electric motors. This method of power utilization is now being extensively employed throughout the country, and a plant is now in process of construction in the southeastern part of Kansas to supply power to three different towns in that section. With this form of service, assuming that the central plant furnishes power to the equivalent of three mills like our type, and that power is transmitted twenty-five miles, the increase in the first cost of the mill would be about \$70,000, this being approximately one-third of the cost of the electrical machinery and building at the central station, the transmission line, and motors to run the mill. The increase in the actual cost of the power will be made up of two items: First, the additional water power to make up for the losses in changing to electrical and back to mechanical power, and the direct loss in transmission; second, depreciation and repairs on the electrical equipment, which will be a larger amount than in the case of the steam machinery. Taking the power loss as twenty per cent., we have 360 horse-power at \$12.50, or \$4500, in the first item. Depreciation and repairs may be taken at six per cent. on \$56,000, which is the cost of the electrical machinery alone, giving \$3360 in the second item. The total increase of power cost over that for water power applied directly is thus \$7860, *or about one-half that for steam power.* Dividends must in this case be paid on an investment nearly ten per cent. greater, however, so that the actual decrease in the rate will be nearly *1.5 per cent.* Undoubtedly this figure can be bettered by the use of electricity for other purposes than running the machinery, or by sale to other parties. This is true particularly in those establishments where portions of the machinery are run during only a part of the time, since individual motors may be used on the machines or groups of machines, and so save the power to drive long lines of idle shafting. In fact, it is often found desirable to use this electric-motor system when the power plant is located directly at the operating plant, in order to save driving so much idle machinery, and when there are several buildings this system is by far the best possible in the great majority of cases, whether water or steam is the prime power.

In this state, however, the power to be depended upon is that transformed from the heat energy stored in the fuels that are available through the agency of some form of heat engine. There are two general classes of these engines. In one the heat of the fuel is applied to some liquid, usually water, in a separate vessel, or boiler, and the vapor thus formed is led to the working cylinder of the engine, where it gives up its heat to produce the energy of moving machine parts. The steam-engine with its boiler is the only practical example of this class. It may use any fuel, as coal, oil, or gas, that will supply the heat. In the other class the fuel is taken into the working cylinder of the engine proper with a supply of air, and there burned. The heat so generated is applied directly to the air present, which with the burned gases forms the working fluid. Of this class the most prominent types are the gas-engine, the oil-engine (using crude petroleum directly), the gasoline-engine, and the kerosene-engine. They are designated as internal-combustion engines.

The fuel used by the gas-engine may be natural gas, artificial gas from the producer used for general gas production, or that from a special form of suction-gas producer, in which the engine in drawing in its fresh charge of air and gas furnishes the draught necessary to maintain combustion in the producer. This last system is becoming popular, due to its economy in operation and the compactness and unity of the plant. Several electric generating plants using this system have been installed in this state during the last few years, and more are in process of erection. The fuel used in the producers now in operation is anthracite coal, but at least one company is now perfecting plans for a producer adapted to the use of the bituminous coal mined in this section of the country. This system is of the greatest importance, since it insures the permanence of the gas-engine so long as the coal supply holds out. Natural gas is good where it may be had and as long as it lasts, but it can hardly be considered as a permanent fuel, and could not be accepted as fulfilling the condition for an abundant source of power.

The oil-engine, using crude petroleum directly as a fuel, has been brought out in the United States in a really satisfactory form by only one company. In this form it is a German design, controlled by the Diesel Motor Company, of New York, and built by the American and British Manufacturing Company in Providence, R. I. In operation, the oil is pumped under high pressure into the engine cylinder, in which air has been compressed to a pressure of 500 pounds to the square inch. The oil is forced in against this

pressure in such a manner that it is sprayed on entering, and the high temperature produced in the air by the compression is sufficient to ignite it. Its cycle is the nearest approach to the ideal cycle first demonstrated by Carnot, the distinguished French scientist and engineer, that has ever been secured in engineering practice. The engine is very efficient and is meeting with a good demand, mostly for use in electric-generating plants, which is the most exacting service to be met. So long as the petroleum supply remains abundant it must be considered as an important prime mover, and in this respect is far superior to the gas-engine using natural gas. Since the fuels used in the two remaining types of internal-combustion engines, namely, gasoline and kerosene, are products of petroleum and comparatively expensive, those forms are not to be considered, excepting at isolated points where small powers are needed.

As machines these two internal-combustion engines which we may consider seriously in the present connection, namely, the gas- and oil-engines, are compact and well constructed, occupying small space in proportion to the power. All are probably familiar with small types of the gas-engine, and it may be that many have in their minds the idea of a small, noisy, and, perhaps, "cranky" affair, which features are sometimes characteristic of the type. An inspection of a large modern engine would do much to dispel that idea. The small engine usually works with but one effective impulse from the combustion or explosion of the gas in two complete revolutions, according to the so-called Otto or four-stroke cycle. This necessitates a very heavy balance-wheel; and increases the difficulties of governing the speed, but it is very generally accepted as the best method of securing efficient utilization of the heat energy of the gas. When large powers are necessary, two or more engines are usually connected to the same shaft, and set so that their impulses alternate, thus securing more uniform expenditure of energy, and making possible extremely accurate governing of the speed. Both vertical and horizontal types are successfully employed.

The latest designs of large power engines by the Westinghouse Machine Company are strikingly similar in general appearance to some makes of tandem compound high-speed steam-engines, excepting for the nature of the valve gear. They have two cylinders in line, with pistons on the same rod, and both cylinders double acting. Hence, instead of having but one impulse in two revolutions or four strokes, each cylinder gives one impulse every two

strokes, and, both together, an impulse for each stroke, or two for each revolution. This places it on a par in this respect with a single-crank steam-engine, and the governing features are good for any service. In the largest sizes it is made still better, however, by having two cranks and rods, with two pairs of cylinders, the cranks being set at ninety degrees with each other, by which method four impulses per revolution are secured. Engines of the single-crank type are made in powers ranging from 200 to 2000 horse-power, and of the double-crank type from 400 to 4000 horse-power. Since very high temperatures are produced in all gas-engines during combustion, sometimes as high as 2800 or 3000 degrees Fahrenheit, which is above the melting-point of cast iron, water circulation in all parts exposed to the heat is necessary, and in the double-acting engines this cooling of the enclosed pistons presents some difficult features in design.

The Diesel oil-engine is built in vertical form, with either two or three cylinders and sets of moving parts, and in general appearance resembles a marine steam-engine. Each cylinder is single acting, giving one impulse in two revolutions, so that the engine as a whole gives either one or one and one-half impulses per revolution, which insures good governing features. The maximum temperature in the cylinder is not far from 1400 degrees Fahrenheit, which is that resulting from the preliminary compression, since the admission of fuel oil is so regulated that it burns during expansion without rise in temperature. The engine is built at present in sizes ranging from 75 to 225 horse-power, but may be readily doubled up on the same shaft and so double the range of power.

As efficient converters of heat into mechanical energy these engines may well be studied in comparison with the steam-engine, since it is with the latter that they come into competition. In this comparison a compound condensing steam-engine will be taken as the type representing the class in large manufacturing plants and for power-station service. A good type of steam-boiler will utilize from 70 to 75 per cent. of the heat in the fuel, as equipped and operated in first-class establishments. The engine of the kind in question will utilize from 14 to 15 per cent. of the heat coming to it in the steam in general service, or 10 to 11.2 per cent. of the total heat value of the fuel burned. The bulk of the remainder of the heat is carried away in the cooling water in the condenser and up the flue from the boilers. The gas- and oil-engines, on the other hand, work with a thermal efficiency of from 17 to 25 per cent., with possibilities of still better results.

As desirable forms of prime movers in commercial plants the gas- and oil-engines must be subjected to complete analysis that shall include all conditions of first cost, depreciation, repairs, and labor, as well as fuel cost. This we will now proceed to do with our typical cotton-mill.

A single gas-engine of 1800 horse-power, to use natural gas, may be purchased for about \$43 per horse-power; foundations will cost about \$7; making the total cost of the engine, erected, \$50 per horse-power, or \$90,000. This is somewhat less than the average first cost of a water-power plant, but the difference is not likely to be enough to influence appreciably the total investment in the mill. Depreciation may be taken at four per cent. and repairs three per cent. on \$90,000, giving \$6300 annually. Labor for attendance, one man, at \$750 per year. Gas consumption will be about ten cubic feet per horse power per hour, or 54,000,000 cubic feet per year of 3000 hours. With gas at 25 cents per 1000 cubic feet, the fuel bill will be \$13,500, and hence the total annual cost of power, \$20,550. This, when compared with the preceding calculations, giving \$22,500 for water power and \$38,000 for steam power, shows well for the gas-engine. When installed with a suction producer, using coal for fuel, conditions will be different. Actual figures for cost of producers of this capacity are not available, but \$10 per horse-power will be a safe figure, which, with \$2000 added to the cost of the engine to provide for the slightly increased size necessary when used with the suction producer, makes the total cost of the apparatus \$110,000. It will be assumed that Arkansas anthracite coal will be used, at \$6 per ton, and that the rate of fuel consumption will be 1.25 pounds of coal per horse-power per hour, which is a liberal figure. This gives 3375 tons of coal burned per year, at a cost of \$20,250. Depreciation and repairs will be increased to seven per cent. of \$110,000, or \$7700, and labor increased by two men, at \$450 each per year, making total labor \$1650 per year. This makes the total cost of power \$29,600 per year, or \$7100 more than the cost of water power. This excess is, however, but forty-five per cent. of that occurring with the use of steam, and is \$760 less than that with water power with electrical transmission and motor drive. As already noted, however, the power cost with the latter system may be reduced under favorable conditions; so it may fairly be stated that costs are about the same for the hydro-electric system and the gas-engine with suction producer.

The first cost of the gas equipment is \$50,000 less, however; so that there would be a difference in dividends in its favor of over

0.5 of one per cent., while there would be a difference of less than one per cent. between it and directly applied water power in New England. Freight differences on raw materials would probably more than counterbalance this difference, so that the cotton-mill in Kansas will be on the same plane with the New England mill as between power cost and freight, while with natural gas at 25 cents per 1000 cubic feet it will be better off on power alone by 0.2 of one per cent. in dividends.

It is almost useless to make calculations for power costs from crude petroleum as a fuel. The price is subject to great fluctuation, and if it should be adopted to any very considerable extent in manufacturing plants it is extremely doubtful if the supply would be adequate, in view of the great demand for the lighter distillates, and in any case the price would greatly increase. Under present conditions in Kansas it offers great advantages as a substitute for coal, especially when used in the oil-engine.

In point of economy in fuel consumption there can be no doubt as to the superiority of the gas- and oil-engines over the steam-engine. This does not mean that the latter is to be at once relegated to the junk heap, however. At the present stage in the development of the internal-combustion engine, its small financial advantage, as shown in the preceding calculations, is often offset by the practical usefulness of steam in auxiliary service, to say nothing of the advantage accruing from the familiarity of operating engineers with the older type.

As it has taken a century and a quarter to develop the steam-engine since it first assumed its practical form in the hands of Watt; so must more time be given to perfect this later type of prime mover which first appeared in really successful operation in 1876. The gas-engine is now passing through a transitional period, while it is coming into prominence as a real factor in the larger business interests of the world. The new form of Westinghouse engine already described shows the manner in which the type is progressing, following instinctively the path of progress marked by the steam-engine, but standing as a more economical machine. It is moving far more rapidly than did the steam machine, and even now, as the latest and most improved steam motor, the turbine, is being perfected and successfully established as a positive step in advance, prominent European scientists and at least one of the prominent engine-building companies of this country are working on the gas-turbine, which we may expect to see making its appearance in the

near future as the latest and most refined result of scientific engine designing of the age.

The commercial development of Kansas of which we speak belongs to the future, perhaps not far distant. The present narrow margin in favor of the gas-engine will be made larger as time goes on, principally by a reduction in the fixed charges for depreciation and repairs, resulting from standardized forms and lower first cost, since the present prices for the engine are abnormally high. Operating engineers are gradually becoming acquainted with it, which in itself will insure increased favor, and there can be no doubt but that in this form of motor Kansas, and other similarly situated states, will find the source of power that will serve in the permanent advancement of the manufacturing interests.